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Ground-based Column Abundance Measurements of Atmospheric Hydroxyl

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## Tropical OH Column Abundance Measurements from Truk, Federated States of Micronesia

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### INTRODUCTION

This report contains the preliminary results of ground-based OH column abundance measurements from Truk, Federated States of Micronesia (7°N), funded jointly by NSF grant #ATM8607193 and NASA grant #NAGW989. These are the first OH column measurements from the tropics, and they constitute a significant contribution to the OH data base we have accumulated from 26°N, 40°N and 65°N. As indicated in the original proposal, we expect these tropical OH data to have a large potential for constraining current models of stratospheric photochemistry and transport. Photochemically, the tropical atmosphere is extremely active all year. An increasing amount of tropical data for other trace species is becoming available, and the mixing ratios of several species of importance to OH photochemistry (e.g. O<sub>3</sub>, H<sub>2</sub>O and CH<sub>4</sub>) show considerable latitudinal gradients [Russell, 1986]. Comparisons of tropical OH behavior with our extensive mid-latitude observations will serve as a critical test of the current understanding of HO<sub>x</sub> photochemistry and its relationship to the other major chemical families. Dynamically, several transport mechanisms operate in the tropics whose effects on trace species are not yet clear. In particular, the quasi-biennial oscillation (QBO) in tropical stratospheric winds exerts a major influence on the Hadley cell vertical transport [Reed, 1964]. Related QBO's in total O<sub>3</sub> [Hasebe, 1983] and in stratospheric H<sub>2</sub>O [Hyson, 1983] have been identified, but QBO effects on other stratospheric species are still unknown. The solar tide in the tropics produces a diurnal surface pressure variation of 2-3 mb; its effect on OH photochemistry in the stratosphere may be significant. The Truk observing site is also within the "fountain" region of the Western Pacific, where an enhancement in tropospheric-stratospheric exchange has been proposed [Newell and Gould-Stewart, 1981].

### RESULTS

In Figures 1-4 we show the Truk OH column abundances obtained in Jan-Feb 1987, June-July 1987, Sep-Oct 1987 and Feb-Mar 1988, respectively. Due to enhanced cloud activity (especially in the summer), the Truk observations do not enjoy the same favorable atmospheric conditions frequently present for the Colorado measurements. However, we have obtained 324 individual measurements from Truk thus far. The OH values are plotted against sec $\chi$ , where  $\chi$ =solar zenith angle, and the reference curve is an empirical fit to the Colorado (40°N) 1981-82 observations published earlier [Burnett and Burnett, 1984]. In all of the figures the sec $\chi$ -dependence is roughly similar to the average Colorado behavior. However, an asymmetry favoring higher PM values can be seen in all four figures. The average PM bias is roughly 18% which is in harmony with an increasing bias observed for decreasing latitude (7% at 40°N and 15% at 26°N [Burnett et al, 1988]). Also, the tropical OH diurnal asymmetry is quite variable, much like our subtropical results, whereas the

mid-latitude asymmetry behaves very consistently. Possible effects by the QBO on the tropical/subtropical OH diurnal asymmetry cannot be discounted at this time.

Figure 5 contains the history of normalized (with respect to the Colorado reference curve) OH abundances from all latitudes. The recent Colorado data exhibit the ongoing seasonal variation documented earlier [Burnett and Burnett, 1984], and the average level is still well above pre-1980 observations. The figure underscores the value of future measurements from Colorado to update this long-term record and for comparisons with results from other latitudes. The Alaska ( $65^{\circ}\text{N}$ ) average abundance from the summer of 1983 is about 40% above Colorado levels. The Florida ( $26^{\circ}\text{N}$ ) data clearly show no seasonal behavior, but instead suggest a biennial pattern. The Truk results will be examined in more detail below.

The Truk measurements are conducted from the U.S. Weather Station, located on the island of Moen. We have access to the results of the station's daily balloon soundings so that we are able to closely monitor atmospheric conditions which may have a bearing on our OH measurements. Figure 6 shows the monthly average zonal wind over Truk from March 1987 through March 1988. The QBO is clearly evident from 18 to 35 km where we have observed roughly one-half of the cycle. Also, an examination of our near UV reference signal indicates behavior which is consistent with the expected increase in total ozone associated with west winds near 24 km. Figure 7 contains the Truk normalized OH abundances for the four observing periods and the corresponding QBO winds from 20 to 30 km. OH abundances appear to be responding to the effects of the QBO, although it is too soon to make a positive correlative claim. A seasonal interpretation cannot be excluded; observations scheduled for the coming fall and in the winter of 1988-89 should resolve this uncertainty.

Finally, Figure 8 shows the Truk OH results obtained during the solar eclipse on March 18, 1988. This was the third occasion on which we made measurements during a solar eclipse [Burnett and Burnett, 1985; Burnett et al, 1988], and all results show the same basic OH response. Although the post-eclipse oscillations observed in Colorado could not be detected in the Florida and Truk cases due to less favorable observing conditions, a large abundance decrease during the eclipse and a post-eclipse overshoot were observed in all cases. The features of the generalized OH abundance response to these eclipses have not been successfully explained to date.

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FIGURES AND FIGURE CAPTIONS

FIGURE 1. OH Vertical Column Abundances vs.  $\sec\chi$ ; Jan-Feb 1987, Truk, FSM. OH vertical column abundances from Truk, Federated States of Micronesia ( $7^{\circ}\text{N}$ ) are plotted against the secant of the solar zenith angle,  $\sec\chi$ . The data represent averages of 155 individual measurements made from 1/22 to 2/27/1987. The solid curve is an empirical fit to 1981-82 measurements from Fritz Peak, Colorado ( $40^{\circ}\text{N}$ ). The overall level of this data is about 10% higher than corresponding Colorado levels.

FIGURE 2. OH Vertical Column Abundances vs.  $\sec\chi$ ; June-July 1987, Truk, FSM. Same as for Figure 1 but for the period from 6/15 to 7/2/1987, representing 23 individual measurements. The average level is about 2% higher than corresponding Colorado levels.

FIGURE 3. OH Vertical Column Abundances vs.  $\sec\chi$ ; Sep-Oct 1987, Truk, FSM. Same as for Figure 1 but for the period from 9/22 to 10/23/1987, representing 66 individual measurements. The average level is about 5% lower than corresponding Colorado levels.

FIGURE 4. OH Vertical Column Abundances vs.  $\sec\chi$ ; Feb-Mar 1988, Truk, FSM. Same as for Figure 1 but for the period from 2/19 to 3/23/1988, representing 80 individual measurements. The average level is about 21% higher than corresponding Colorado levels.

FIGURE 5. Normalized OH Abundances from All Latitudes. Normalized data are the measured abundances divided by the corresponding values from the Colorado 1981-82 reference curve. Over 10 years of observations from Fritz Peak, CO ( $40^{\circ}\text{N}$ ) are shown at the top. At the bottom are plotted the normalized abundances from Boca Raton, FL ( $26^{\circ}\text{N}$ ), Poker Flat AK ( $65^{\circ}\text{N}$ ) and Truk, FSM ( $7^{\circ}\text{N}$ ).

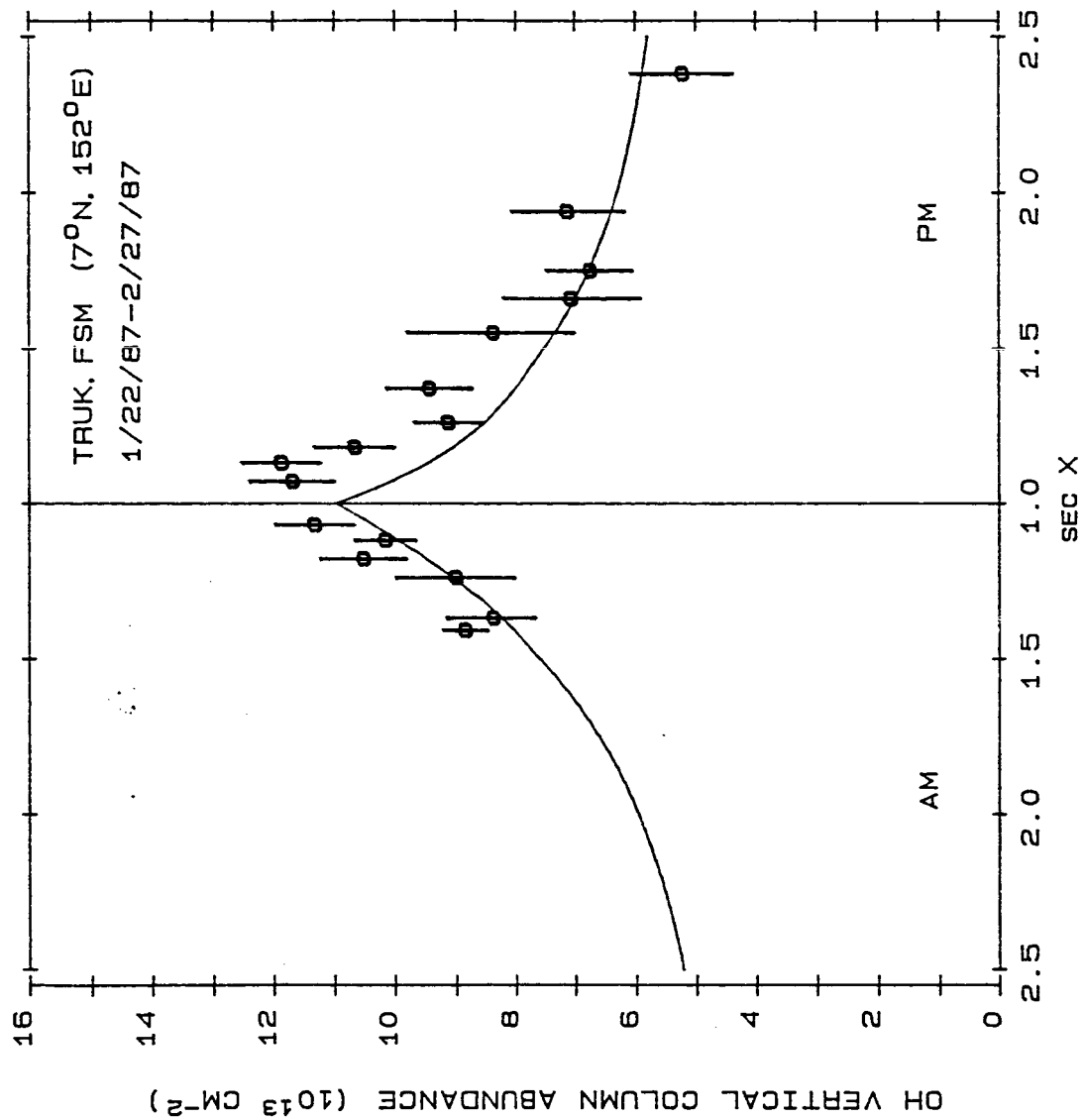


FIGURE 1

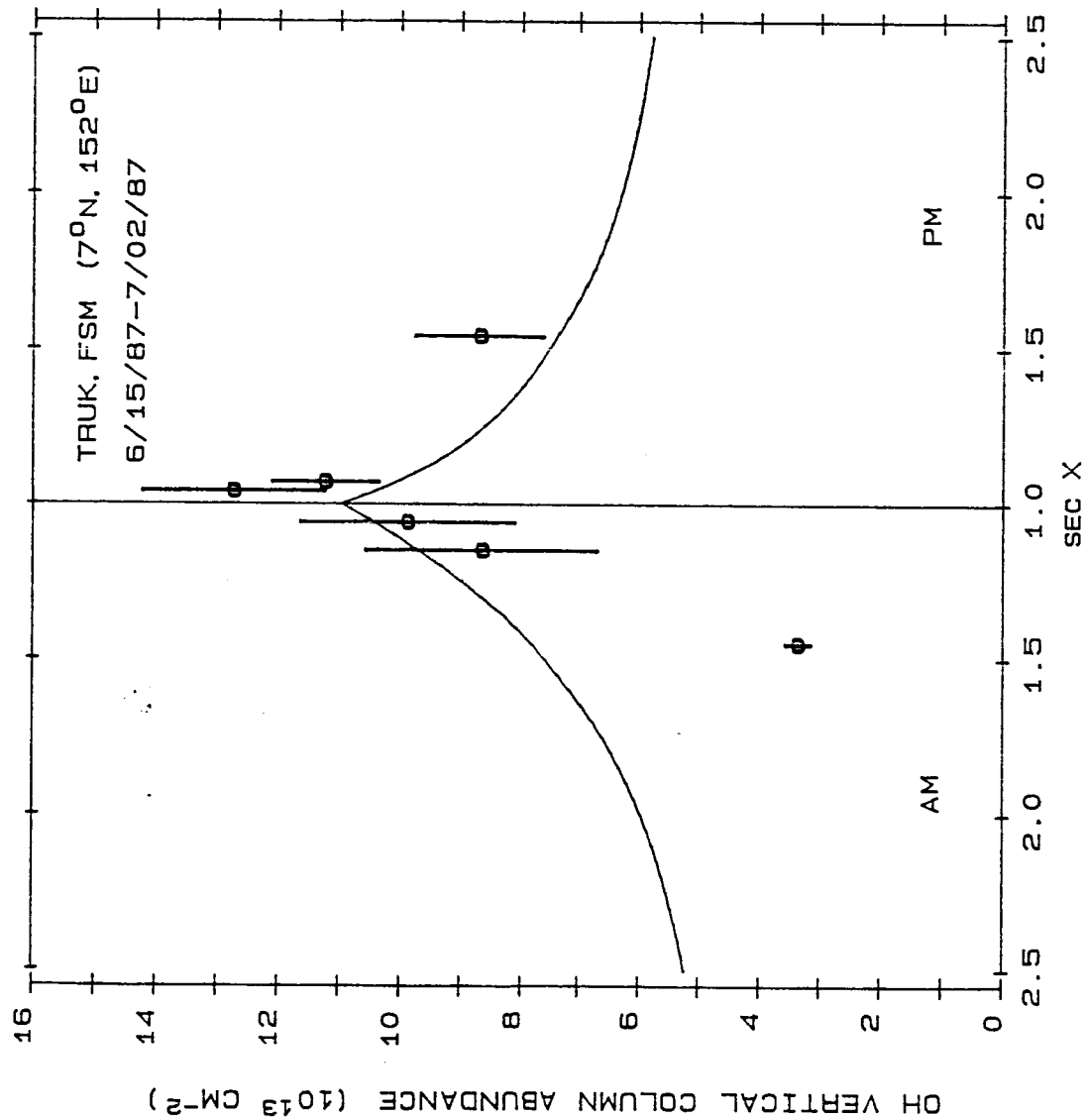


FIGURE 2

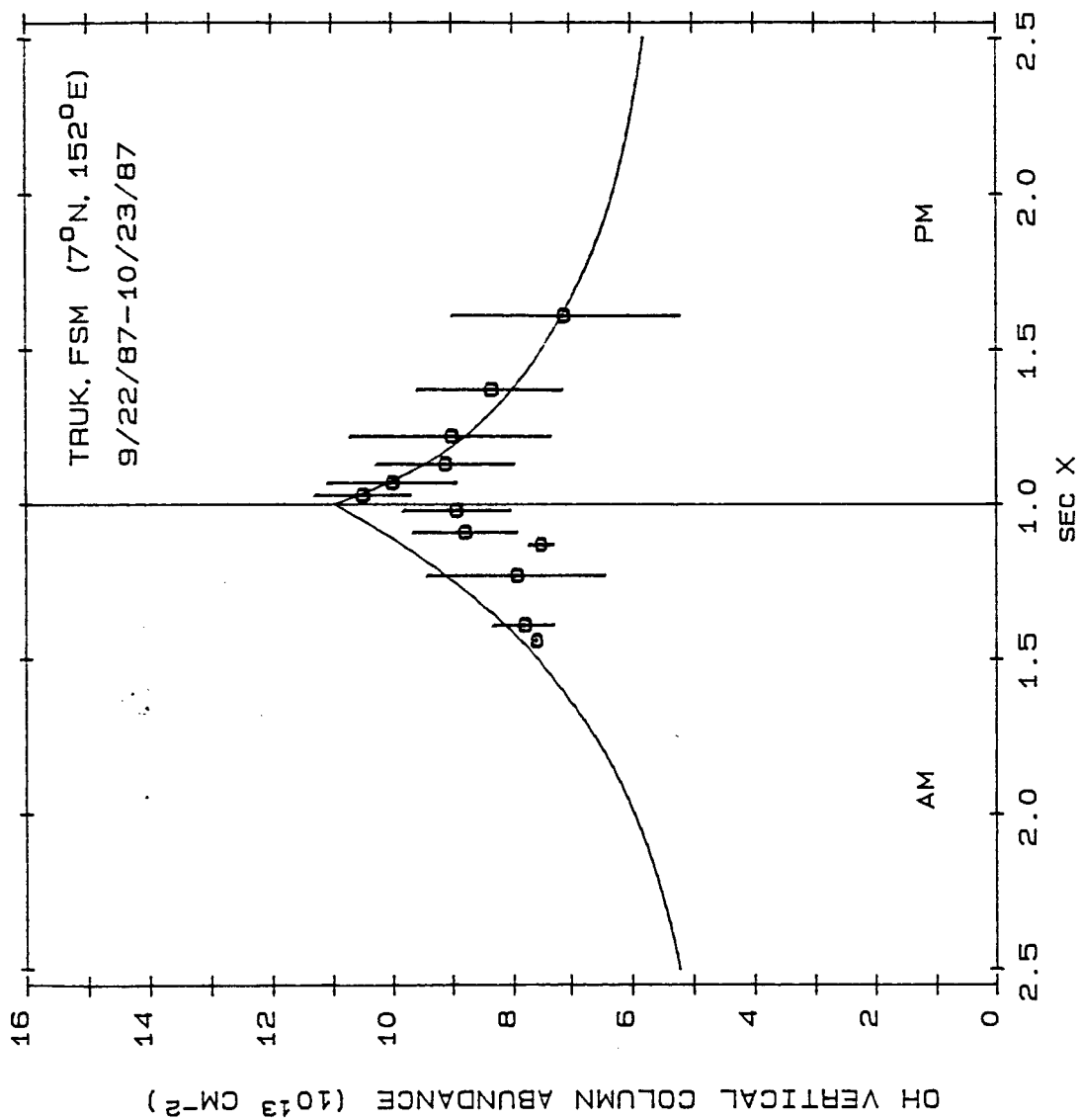


FIGURE 3



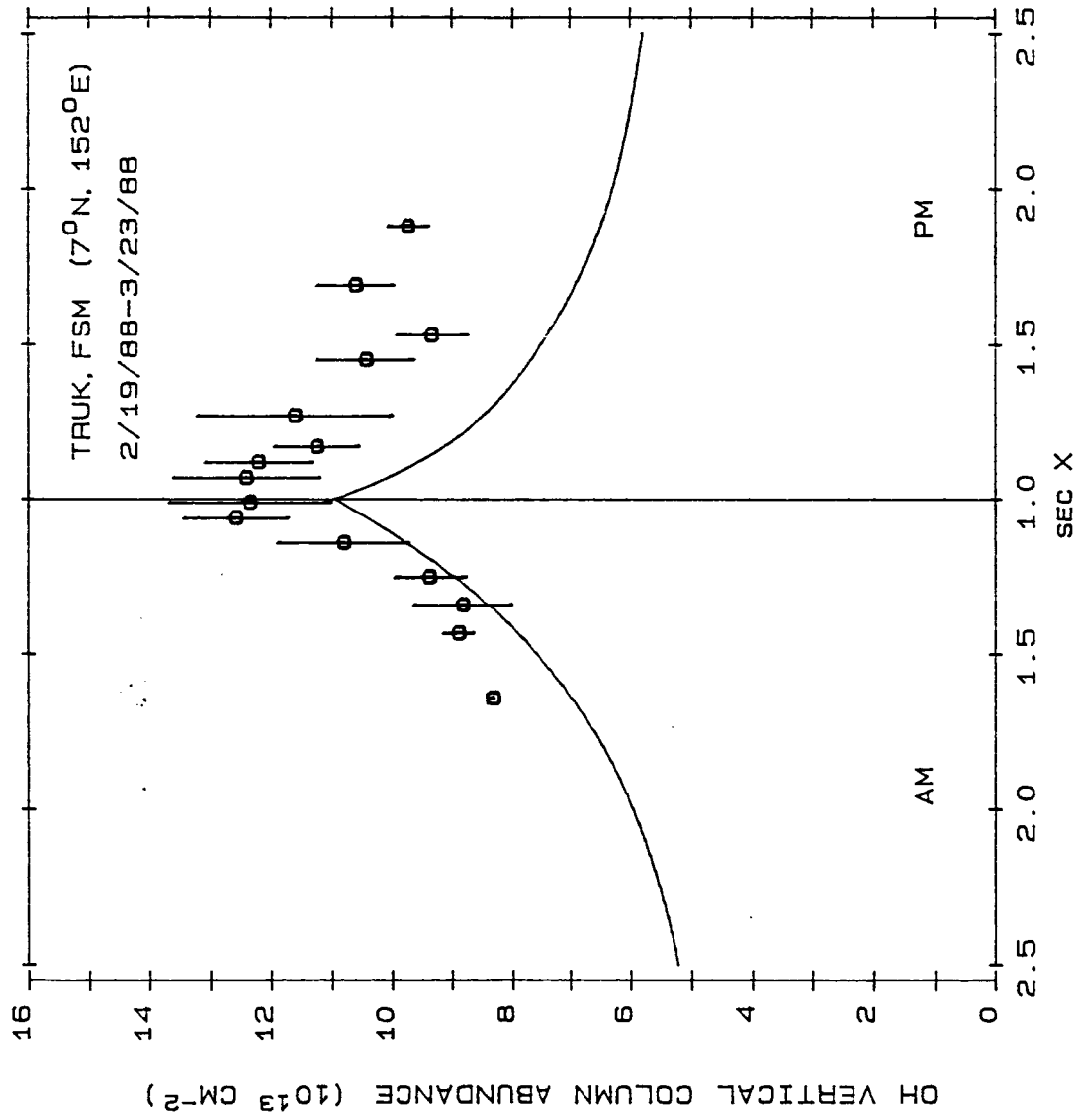


FIGURE 4

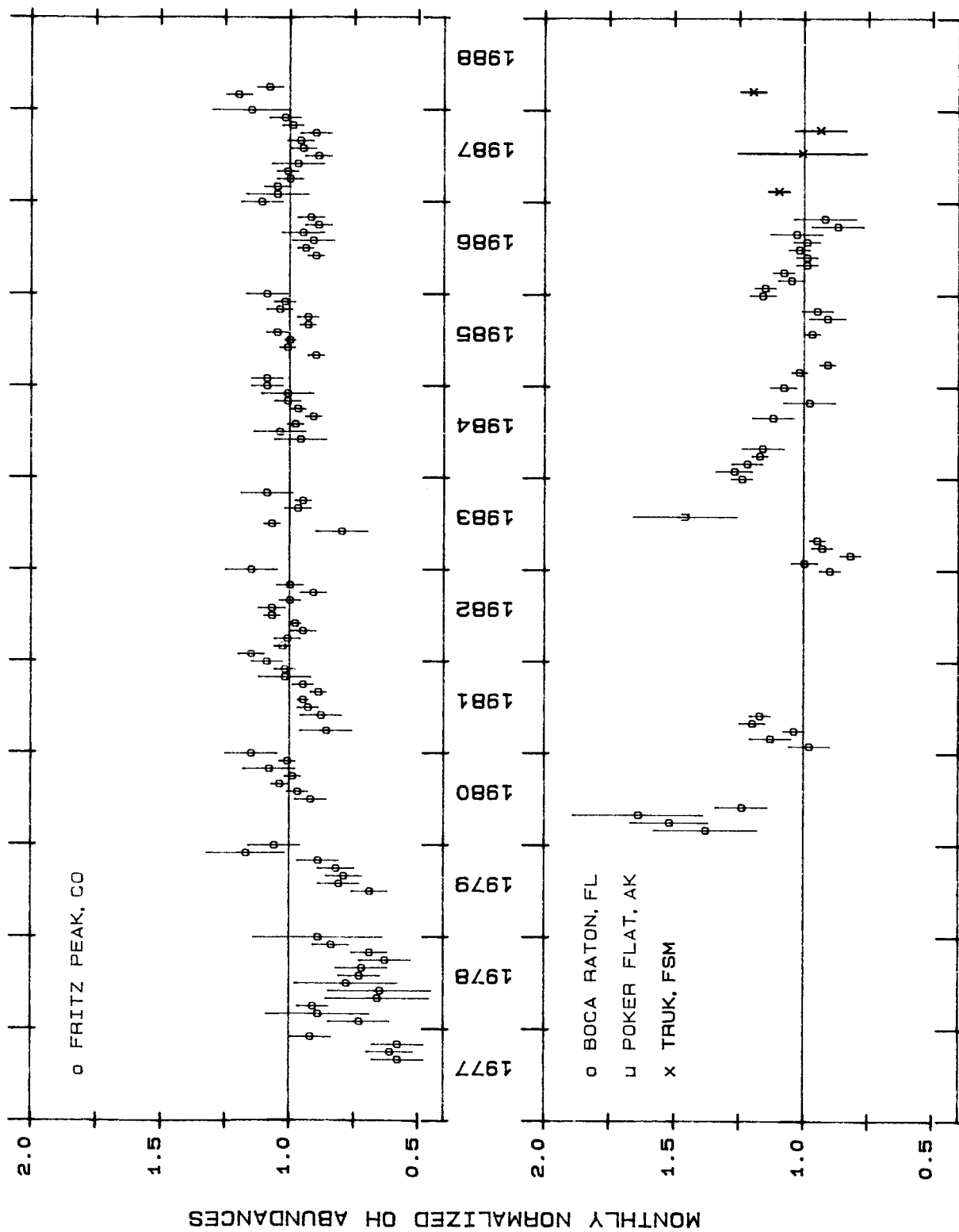


FIGURE 5

FIGURE 6. 1987-88 Zonal Winds Over Truk, FSM.

The zonal winds as determined from balloonsonde measurements by the US Weather Service are plotted as a function of altitude. The quasi-biennial oscillation (QBO) in tropical lower-stratospheric winds is clearly evident from 18 to 35 km. In March of 1987, the stratospheric wind was from the east with a maximum of 30 m/s occurring at 30 km. In the succeeding six months, this maximum decreased in intensity and altitude to about 20 m/s at 20 km in September. Westerly winds from 25 to 35 km began to appear at this time, and by January of 1988 westerlies of about 15 m/s dominated from 20 to 30 km. In February and March of 1988 the westerlies began propagating downward and decreasing in intensity; meanwhile the easterlies showed signs of returning above 30 km. These results are in good agreement with more comprehensive characterizations of the QBO [Reed, 1964; Naujokat, 1986].

FIGURE 7. Normalized OH Abundances and Zonal Winds from Truk, FSM.

Shown are the time series of normalized OH abundances and zonal winds over Truk, Federated States of Micronesia. The OH data display the trend observed in Figure 5, and the wind data show the phase propagation of the QBO half cycle seen in Figure 6. The figure suggests that OH abundances are responding to the effects of the QBO, although future measurements are required to substantiate this interpretation.

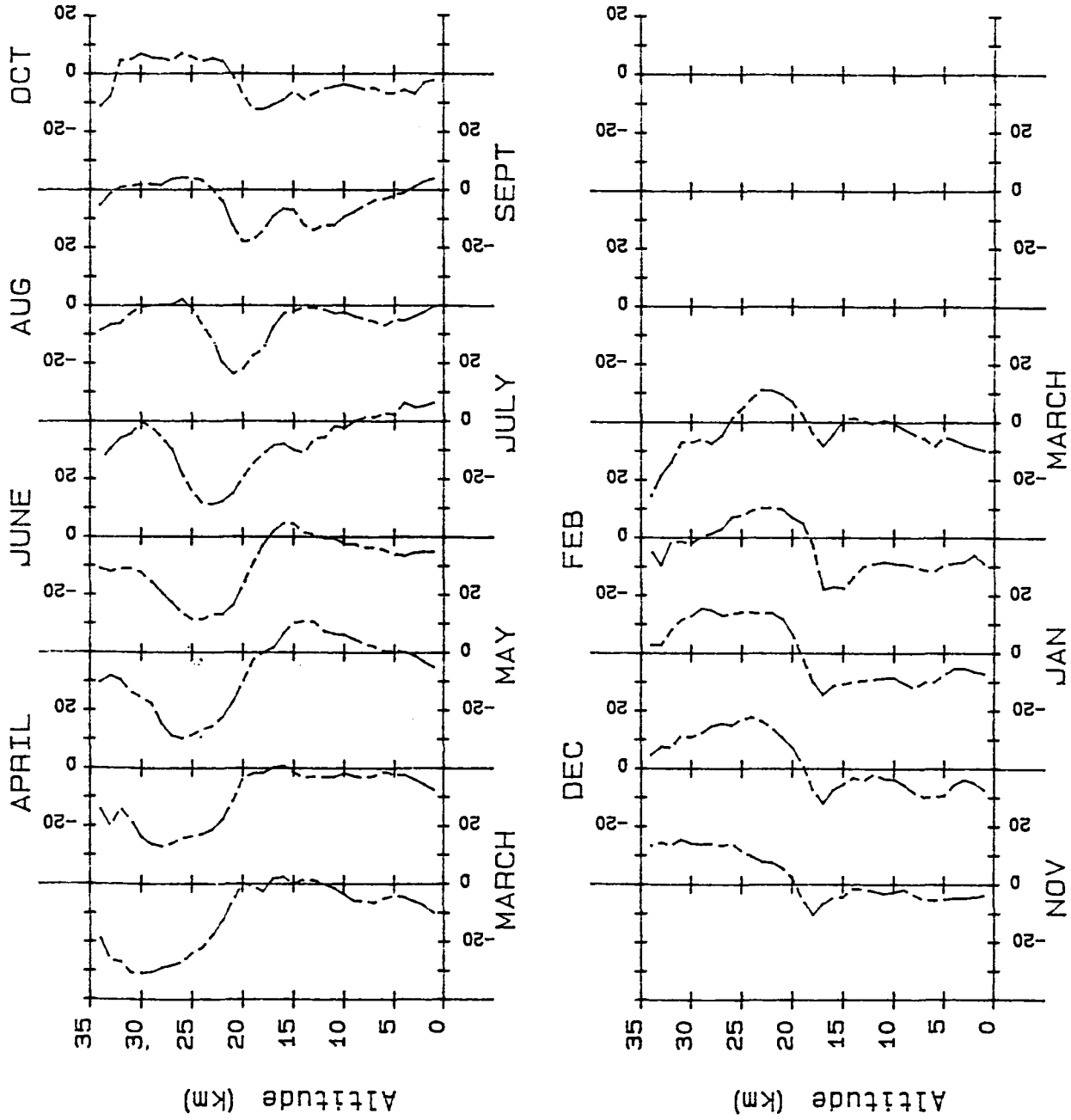


FIGURE 6 1987-88 Truk Zonal Winds (m/s); E-neg, W-pos

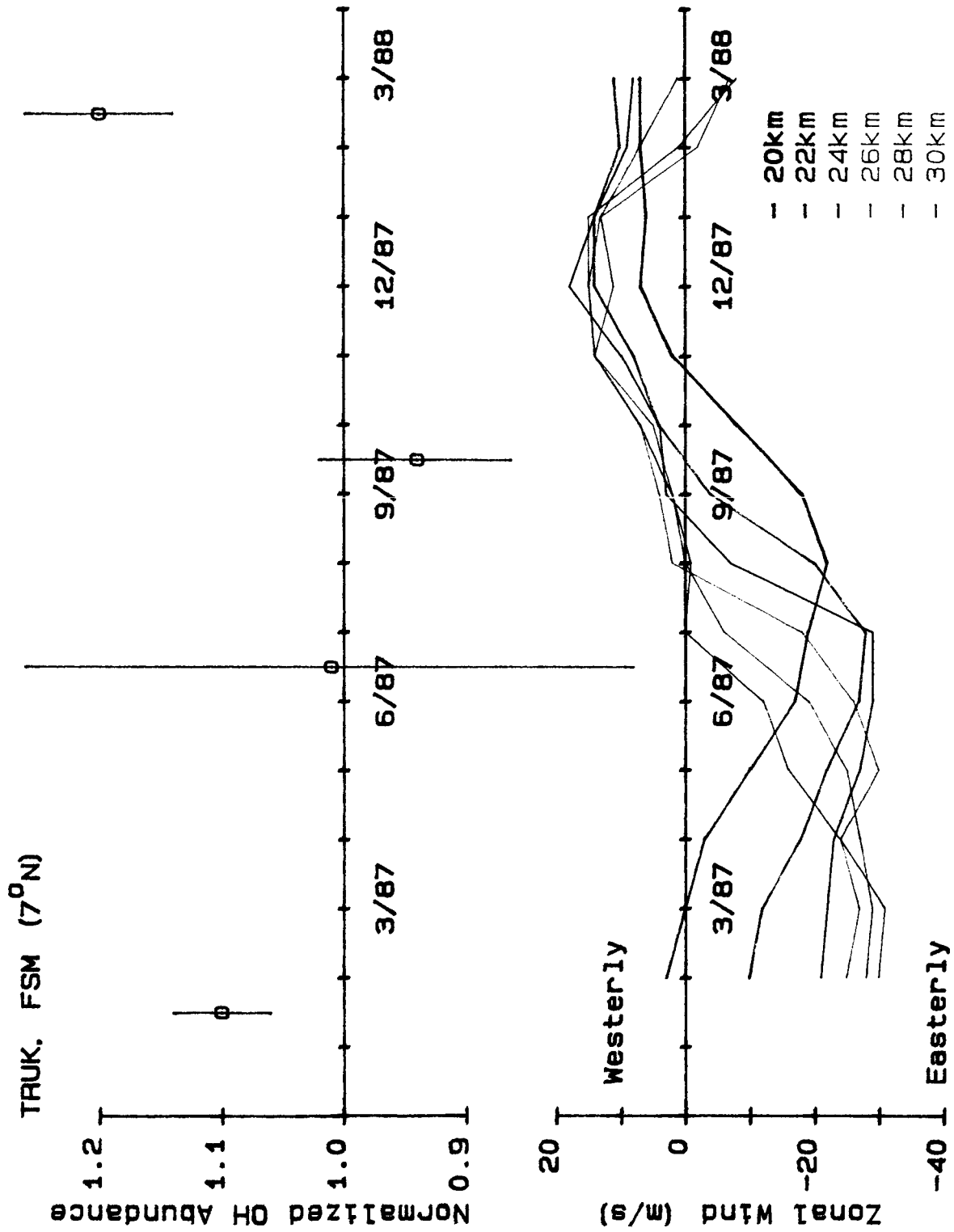


FIGURE 7

FIGURE 8. Eclipse of March 18, 1988 from Truk, FSM.

Figure 8 shows the OH abundance response to the total solar eclipse of March 18, 1988. This behavior is similar that observed for the partial solar eclipse of Oct 3, 1986 at Boca Raton FL [Burnett et al, 1988], and the partial solar eclipse of May 30, 1984 at Fritz Peak CO [Burnett and Burnett, 1985]. Observing conditions were not as favorable in Truk as they were during the Colorado eclipse, thus the data contain higher uncertainties and the time resolution is considerably lower. Nevertheless, the major features of the OH eclipse response were reproduced quite well. The path of totality passed to the northwest of Truk, and an occultation  $\approx 30\%$  occurred at the observing site just before local noon. Shown in the figure are the OH abundances for the day of the eclipse (o's) plotted with respect to local time, along with the average abundances (x's) for the Feb-Mar observing period. The bottom figure shows the UV reference signal on March 18 normalized with respect to the average signal for Feb-Mar. This signal is a direct indicator of changes in ground-level near UV radiation, and it is seen to track the eclipse quite well; concomitant changes in OH abundances also occurred. The OH abundances decreased to  $\approx 40\%$  below average during maximum occultation. The subsequent OH abundance recovery was rapid, and in fact the abundances overshoot the average level by  $\approx 45\%$ . Both the decrease and overshoot were beyond the uncertainty in the measurements. The OH decrease which occurred during all three eclipses is larger than can be explained by the changes in solar flux alone, and no known mechanism can account for the overshoot observed on all three occasions.

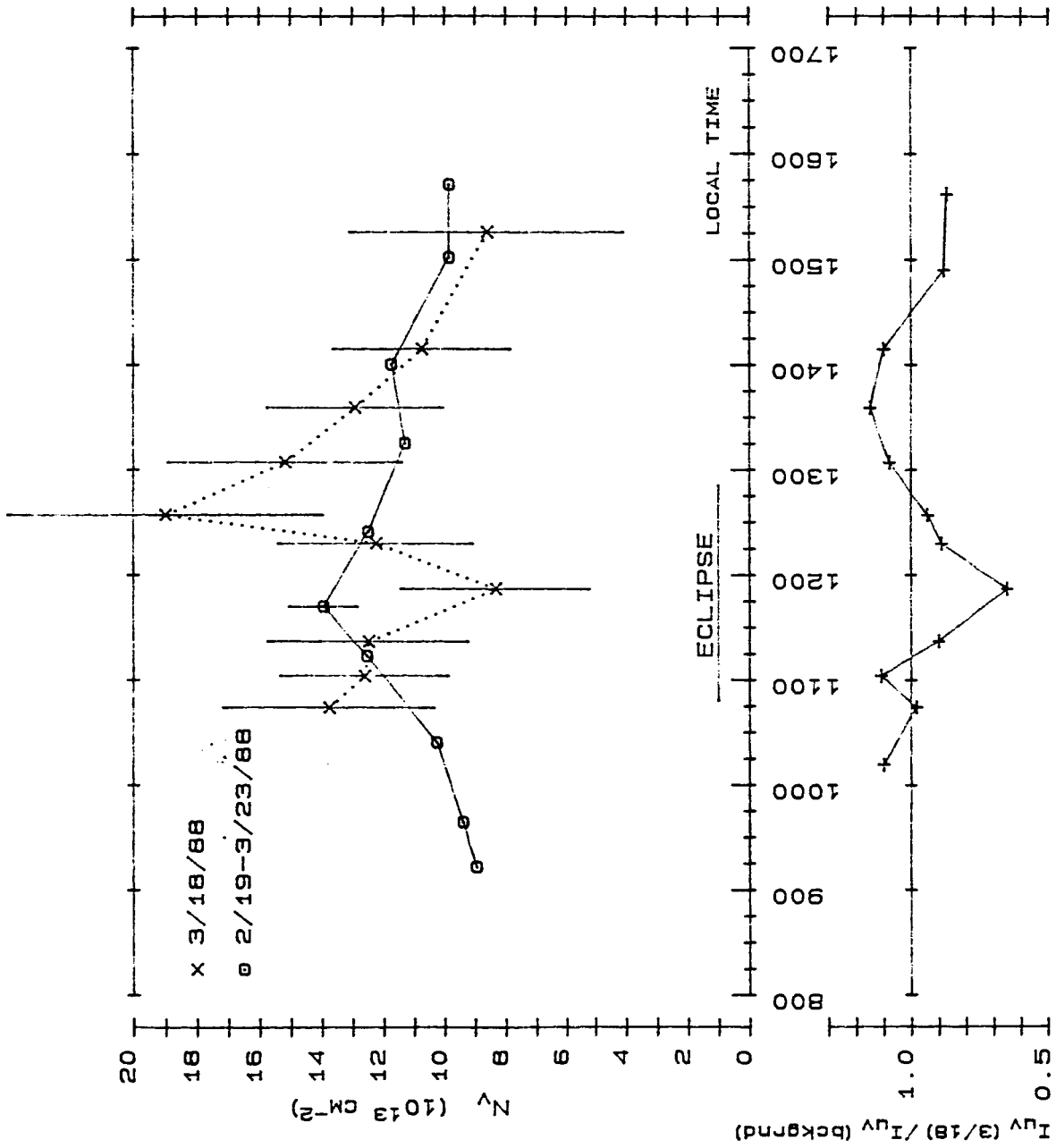


FIGURE 8 Eclipse of March 18, 1988